DACA4202-R-0025

Plug Power, Inc.

Final Project Report – FY02 PEM Fuel Cell Demonstration

Proton Exchange Membrane (PEM) Fuel Cell Demonstration
Of Domestically Produced PEM Fuel Cells in Military Facilities

US Army Corps of Engineers
Engineer Research and Development Center
Construction Engineering Research Laboratory
Broad Agency Announcement CERL-BAA-FY02

United States Naval Support Unit (NSU) – Saratoga Springs, NY

7/8/04

Executive Summary

Plug Power Inc. installed and operated eight (8) natural gas fueled, Combined Heat and Power Fuel Cell Systems (CHP Systems) at the Naval Support Unit, Saratoga Springs, NY (NSU) Quiet Harbor housing complex. The 5kW CHP Systems, manufactured by Plug Power Inc. incorporated combined heat and power capability to provide electricity and allow recovered waste heat from the CHP Systems to provide heat for domestic hot water. Additionally, the CHP Systems incorporated standby capability to allow the units to operate during periods of electric utility grid (Grid) outage. Plug Power Inc. served as the manufacturer, installer and service provider for this project.

The eight (8) natural gas CHP fuel cell systems were installed to provide electricity and hot water to four separate apartment buildings. The Quiet Harbor complex is operated by the NSU, Saratoga Springs, which provides logistic and base operating support, comptroller and supply services (not directly related to training) to the Naval Nuclear Power Training Unit, Ballston Spa, New York. The NSU also provides administrative, morale, welfare and recreation and personal property and housing services for the Department of Defense activities and related personnel. The Quiet Harbor community includes twenty-five (25) four-unit townhouse style buildings containing a total of one hundred (100) units. Each group of four units is served by forced hot air heat and an eighty-gallon natural gas fired hot water heater. Niagara Mohawk Power Corporation individually meters electricity supply to each of the units. Complete installation cost for the project was $67,950.

The host site point of contact for the Naval Support Unit is:
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Proposal – Proton Exchange Membrane (PEM) Fuel Cell Demonstration of Domestically Produced Residential PEM Fuel Cells in Military Facilities

1.0 Descriptive Title

Combined Heat and Power Fuel Cell System (CHP System) Demonstration at the Naval Support Unit, Saratoga Springs, NY.

2.0 Name, Address and Related Company Information

Plug Power Inc.
968 Albany-Shaker Rd.
Latham, NY 12110

Data Universal Numbering System (DUNS) Number: 159700830
Commercial and Government Entity (CAGE) Code: 2AAT3
Taxpayer Identification Number (TIN): 223672377

Plug Power Inc. (Plug Power) designs, develops and manufactures on-site electric power generation systems utilizing proton exchange membrane (PEM) fuel cells for stationary applications. Plug Power's fuel cell systems will be sold globally through a joint venture with General Electric and through DTE Energy Technologies in a four-state territory, which includes Michigan, Illinois, Ohio and Indiana. The Company's headquarters are located in Latham, N.Y., with offices in Washington, D.C., and The Netherlands.

3.0 Production Capability of the Manufacturer

CHP Systems are manufactured at Plug Power's Latham, New York manufacturing facility. This facility, which opened in February 2000, is comprised of 50,000 square feet of dedicated production and production test facilities. Plug Power employs approximately 100 personnel in its production areas. The production processes are designed around the principles of Lean Manufacturing, and use the Toyota Production System as a model. As such, planning and production is via a "pull system" that is, systems are produced only as orders pull demand for product through the production system. Lead-time for delivery is between eight (8) and twelve (12) weeks for large orders, smaller orders (less than ten) can be fulfilled immediately. Current production capability allows for the manufacture of approximately five (5) units per week with the ability to significantly increase this rate.

4.0 Principal Investigator(s)

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6.0 Past Relevant Performance Information

Long Island Power Authority
333 Earle Ovington Blvd
Suite 403
Uniondale, NY 11553
POC: Mr. Daniel Zaweski, (516) 719-9886
Project Title: Fuel Cell Demonstration Program
Contract Identification Number: N/A

- Contract Award Date: May 15, 2001
- Contract Amount: $7M
- Contract Award Date: February 22, 2002
- Contract Amount: $3.6M

New York State Energy Research and Development Authority
17 Columbia Circle
Albany, NY 12203-6399
POC: Mr. James Foster, (518) 862-1090 x3376
Project Title: Fuel Cell Demonstration Project
Contract Identification Number: No. 4870 - ERTER - BA - 99

- Contract Award Date: January 25, 1999
- Contract Amount: $3M

National Fuel Gas Corporation
10 Lafayette Square
Buffalo, NY 14203
POC: Mr. Rob Eck, (716) 857-7711
Project Title: Residential Fuel Cell Demonstration Project
Contract Identification Number: N/A

- Contract Award Date: February, 2002
- Contract Amount: $200K

7.0 Host Facility Information

The Saratoga Springs Naval Support Unit (NSU) - Quiet Harbor complex provides logistic and base operating support, comptroller duties and supply services (not directly related to training) to the Naval Nuclear Power Training Unit, Ballston Spa, New York. The NSU also provides administrative, morale, welfare and recreation and personal property and housing services for the Department of Defense activities and related personnel. The Quiet Harbor community includes twenty-five (25) four-unit townhouse style buildings containing a total of one hundred (100) units. Each group of four units has a common mechanical room and is served by forced hot air heat and an eighty- (80) gallon natural gas fired hot water heater. Electricity and natural gas services to the complex are provided by Niagara Mohawk Power Corporation.

8.0 Fuel Cell Installation

Plug Power and NSU personnel identified four (4) townhouse buildings within the complex for the fuel cell installation – buildings 16, 17, 20 and 21. Table 1 shows the average electric demand for each site (information provided by the NSU).

Table 1: Quiet Harbor Installation Sites

Fuel Cell Site *	Number of Systems	Operating Profile Steady State	Monthly Average - Production	Monthly Average - Demand	Expected % of Demand Provided *
		kW	Kilowatt-hours	Kilowatt-hours	
16 Quiet Harbor Dr	2	2.5	3600	2447	147%
17 Quiet Harbor Dr	2	2.5	3600	2473	146%

20 Quiet Harbor Dr	2	2.5	3600	2543	142%
21 Quiet Harbor Dr	2	2.5	3600	2616	138%

* Demand at each Fuel Cell Site includes 4 apartments and 1 mechanical room

There were two (2) fuel cell systems at each site:

- The upstairs apartments (C & D) at each site were electrically fed by one fuel cell system per apartment.
- The fuel cells operated at 2.5kW steady state. Periodically, the systems were turned up to 4.0kW or 5.0kW to verify operation at high power levels.
- Thermally, the fuel cells were joined together and supplemented the common hot water system in the mechanical room.
- In standby mode, the fuel cells continued to power the entire main apartment panels with the exception of the 240 VAC electric clothes dryer.

An extensive data monitoring and wireless LAN setup was installed to maximize the data recovered during the demonstration. A high-speed internet connection transmits detailed system data with a resolution equivalent to that in the Plug Power laboratory.

Plug Power retained Industrial Process Design, Inc. (IPDI) for their engineering and general contracting services during the installation phase of this project. The scope of work included development of an engineering package containing all details of site construction, foundation preparation, installation of the natural gas, water and CHP systems, electrical interconnection and all miscellaneous piping, conduit, wiring and construction coordination activities. All work was performed under a lump-sum contract for a total of $67,950 or approximately $8,500 per system. IPDI held two sub-contracts for completion of the electrical and mechanical work. When construction was complete, a certified electrical inspector verified the installation and Niagara Mohawk performed an interconnection review and verification of the automatic and manual disconnect equipment. An installation timeline showing major milestones can be found in Table 2. More details can be found in the installation schematic in Appendix C.

Table 2: Installation Timeline

Completion Date	**Task**
November 27, 2002	**Contract signed by all parties**
November 28, 2002	Start site engineering
December 4, 2002	Foundation preparation for fuel cell placement
December 5, 2002	**System delivery and rigging**
December 24, 2002	Engineering package completed and approved by Plug Power
January 9, 2003	Start electrical construction
January 9, 2003	Start mechanical construction
February 27, 2003	Final electrical connections by Plug Power
February 27, 2003	Finish electrical construction
February 27, 2003	Finish mechanical construction
February 27, 2003	Initial system start-ups
February 27, 2003	**Town hall meeting and site walk-through**
March 13, 2003	Electrical inspection
March 13, 2003	Niagara Mohawk interconnection verification test
April 28, 2003	Installation of protective, wooden pipe covers
April 28, 2003	System repairs to address freeze damage from extended cold weather storage
April 29, 2003	**Commissioning of fuel cell systems**

During the site selection phase (Spring 2002), the main concerns were with location of utility connections and logistics for shipping, rigging and construction. A typical site/mechanical room serving one of the townhouse buildings is shown in Figures 1 and 2. The natural gas, communications, electrical equipment and water supply are all readily accessible. Clearance for rigging was more than adequate and space for the crew to work was generous.

Fig. 1

Fig. 2

The systems were delivered to the NSU in December 2002 and were stored outdoors, at their respective sites, until construction was finished in February of 2003. Upon initial startup of the machines, freeze issues became apparent. New failure modes were found on these units including heat exchanger failures and stack perforations due to ice formation within the MEA assembly. Residual water left over from Plug Power in-house testing was identified as the root cause and subsequent procedural changes have been made to remove it prior to shipment. It has since been learned that there are areas within the system (i.e. heat exchangers) that cannot be satisfactorily drained of water without disassembling the subsystems and performing elaborate and impractical procedures. These discoveries have been the impetus for the freeze protection/reaction planning developed by the Plug Power Engineering team that was initiated in the winter of 2003. This plan focuses on early warning, quick response and freeze prevention through the use of space heaters. Previously, the units would be allowed to freeze and would be thawed prior to restart with space heaters. This change in approach dramatically decreased the amount of labor and expense needed to bring a frozen system back on-line.

It is important that design efforts continue around the ability for any outdoor system to be freezable or freeze proof. The “rapid response” plan may prove to be a cost-effective and acceptable containment action for dealing with 10 to 12 systems but is not a long-term solution for a large fleet.

Additionally, the severe winter of 2003 amplified certain site characteristics that otherwise would not have been a concern. The primary issues with the NSU sites were: ice formation on the roof above the systems (Fig 3) and the lack of winter accessibility due to snow build-up (Fig 4).


Fig. 3


Fig. 4

According to site personnel, this level of ice formation and snow build-up has never occurred before. While that may be true, it is incumbent that site planning address this type of issue for future installations. The result could have been serious had one of the large ice pieces fallen on a Technician or an energized gas line.

To protect against mechanical damage, Plug Power fabricated wooden covers for the pipes. These covers can be seen in the completed site photographs below. For future installations, certain questions must be answered as part of the site selection process. For example:

- How would a severe snow/ice storm affect the site?
- Is there a possibility that ice build-up (even moderate) could cause damage to the system or piping below?
- Is the minimum spacing from the building (as required in the installation manual) enough?
- Should supply lines be run underground?
- What about heavy rain?
- Are there any other precautions that should be taken against the effects of strong or extended periods of bad weather?
-

<u>Completed Site Photographs</u>

Bldg. 16 (Systems B175 & B176)

Bldg. 17 (Systems B173 & B174)

Bldg. 20 (Systems B170 & B171)

Bldg. 21 (Systems B168 & B169)

Typical Mechanical Rm. (showing data server)

9.0 Electrical System

The GenSys™ 5CS PEM fuel cell system has a 120 VAC @ 60 Hz output. The fuel cell system is rated for 5 kW (5 kVA) maximum, and 10 kVA for 5 seconds of overload conditions. The minimum set point is 2.5 kW (2.5 kVA). In standby mode, the system will follow any 0 to 5 kW load at the critical load panel (see mode descriptions below). The electrical output is single-phase line to neutral with a separate ground and the system has a unity power factor, pf = 1.0.

The GenSys™ 5CS is considered a utility interactive current source that automatically synchronizes itself to the grid's voltage and frequency. The inverter has a microprocessor-based controller that senses the grid, feeds the signal back and outputs the matching, synchronized signal. The inverter was designed to automatically isolate itself if an over/under voltage or frequency is experienced. Furthermore, the inverter has a circuit breaker that will trip if over current is experienced from the grid. Islanding protection is certified by Underwriters Laboratories to the UL 1741 standard.

An automatic transfer switch is internal to the inverter and a manual disconnect switch is mounted near the system. Other than the electrical output connections, the customer is not required to provide auxiliary power to the unit. Internal batteries and the grid provide all the power necessary for start-ups, transients, shutdowns, etc. The system can start up independent of grid status but will not export to the grid unless normal grid conditions exist

Mode Description - The GenSys™ 5CS:

- Grid parallel: This is the standard operating mode of the fuel cell system. The system generates power at a fixed set point and exports it to the facility. Unused power is sent to the grid or, if more power is needed, it will be taken from the grid. This is accomplished by back-feeding a 50-amp breaker in an existing electrical panel. In this type of interconnection, if the grid fails, the system will safely isolate itself from the grid. Upon return of the grid, the system will synchronize itself and reconnect with the grid.

- Standby: If this feature is used, the fuel cell will continue to provide electricity to critical loads in the event of a grid failure. A separate critical load panel must be installed to use this feature. Up to 4.5kW of critical circuits are wired in from the existing electrical panel and will remain powered if there is a power outage. Upon return of the grid, the system will synchronize itself and switch back to a grid parallel mode. This feature was successfully demonstrated during the major northeast blackout in August 2003. During that prolonged grid outage, the eight apartments fed by fuel cells remained completely powered while the other 92 apartments were left in the dark.

The standby function is an important system characteristic that many customers and site hosts find attractive. The problem, however, comes with the integration of the feature into existing construction. For this case, the customer sub-panels (where the critical loads would be taken from) were buried in closet walls within the apartments – not in the mechanical rooms (or basement of a house) as envisioned by the system designers. The result, if the team were to follow the installation manual, would have been a prohibitively expensive critical load panel (CLP) installation with a significant amount of money dedicated to aesthetic issues and exploratory work within the sheet-rocked walls of the apartments.

Instead of installing the CLP, the existing apartment panel was wired to the inverter critical "load" output. This serves the same function as the CLP but required the design and installation of two additional protective devices, a fused terminal block panel in the mechanical room and a voltage sensing control circuit in the apartment panel. The fuse panel protects the wiring from the mechanical room to the apartment panel and the control circuit prevents 240-volt loads from back feeding the utility. The result was that the main apartment sub-panel also served as the CLP. With the exception of the 240V clothes dryer, all apartment loads were kept energized in the event of a grid outage.

An unexpected discovery indicated an issue with the MP 5000 inverter and resulted in loss of critical loads. A few CLP circuit fuses, which were rated for high inrush current, failed. It was theorized that the MP 5000 inverter was causing an inrush that resulted in the fuses prematurely degrading and failing. The fuses were replaced with circuit breakers. The circuit breakers were more expensive but eliminated the inrush trip issue. Further investigation indicated that an inverter rewire could provide a short-term containment fix for this problem.

In addition, Plug Power offers a Customer Interface Panel (CIP). The CIP gives the end user the ability to change power setpoints and shut the system down. Installation can be costly when long, tortuous runs are required. A wireless configuration may be an opportunity for simplification.

10.0 Thermal Recovery System

The CHP heat recovery loop is an external system that circulates a heat transfer fluid (typically propylene-glycol/water mixture) from the fuel cell to the point of use (baseboard heat, hot water tank, etc.). The fuel cell system is designed to operate normally if there is no CHP loop installed or if the customer demand at any time is zero. The excess heat generated by the fuel cell will simply be discharged through the existing radiator.

The external CHP loop should be designed to meet the following specifications:

- Flow: 0-10 gpm (1-2 gpm will maximize heat reclamation from the fuel cell)
- Pressure: <= 30 psig
- Temperature: (installation specific) with a flow rate of 1-2 gpm, the return temperature to the customer-supplied system will be approximately 140^oF
- Available heat:
    - 11,200 BTU/hr @ 2.5kWe
    - 21,900 BTU/hr @ 4.0kWe
    - 27,000 BTU/hr @ 5.0kWe

The NSU installation combined the thermal output of two GenSys™ 5CS systems and used the heat to supplement the existing 80-gallon gas fired hot water tank common in each mechanical room. See Appendix E for details. The existing 80-gallon tank serves all four apartments and is the sole source of hot, potable water for the residents. The CHP usage pattern can be best described as a batch heating process followed by a maintenance cycle. As the residents consumed hot water, the CHP loop would act to bring the fresh water in the tank up to temperature (~135 ^oF). When the tank temperature setpoint was reached, the CHP loop would maintain the temperature while it waited for another period of water usage. A BTU meter was installed at the Building 21 site to monitor the thermal performance of the CHP loop.

A new CHP configuration was tried for the first time at the NSU facility. Plug Power tied the CHP loop directly into the potable water system for the apartments. Typically, a heat exchanger or additional water tank and pump would be installed to provide two layers of separation/protection between potable water and propylene glycol mixtures. This extra equipment drove cost up and overall efficiency down. Plug Power was able to avoid the added cost/complexity of this equipment because of a new declaration in the Plumbing Code of New York State – 2002. The Plumbing Code states:

> Chapter P2 - Definitions
> **ESSENTIALLY NONTOXIC TRANSFER FLUIDS.** Fluids having a Gosselin rating of 1, **including propylene glycol**; mineral oil; polydimethylsiloxane; hydrochlorofluorocarbon, chlorofluorocarbon and hydrofluorocarbon refrigerants; and FDA-approved boiler water additives for steam boilers.
>
> Chapter P6 – Water Supply and Distribution
> §P608 – Protection of Potable Water Supply
> §P608.16.3 Heat exchangers. Heat exchangers utilizing an essentially toxic transfer fluid shall be separated from the potable water by double-wall construction. An air gap open to the atmosphere shall be provided between the two walls**. Heat exchangers utilizing an essentially nontoxic transfer fluid shall be permitted to be of single-wall construction.**

These declarations, along with approval by the Navy, enabled Plug Power to connect the CHP loop directly to the potable water system in the mechanical room. The result was a cheaper, more efficient system. However, there were a number of lessons learned that are directly transferable to future projects.

- Plumbing compatibility – the introduction of potable water into the fuel cell system required some changes to the installation and to the machine itself. New plumbing internal and external to the fuel cell was required to meet FDA compatibility and pressure requirements for potable water applications.
- Freezing issues – typically, a propylene glycol and water mixture is used as the CHP loop heat transfer fluid. By introducing pure water into the fuel cell, all external piping from the building to the machine required electrical heat tracing.
- BTU meter and deposit buildup – The potable water installation resulted in an open loop system where fresh water, complete with minerals and deposit forming material, was constantly circulated through the CHP plumbing. In addition, a pre-existing sediment layer on the bottom of the hot water tank was disrupted and circulated through the piping system. The sediment was eventually cleaned out after a series of system flushes. The constant introduction of fresh water however, continued to form deposits on the turbine flow meter of the BTU meter installed at building 21. The result was that the meter would seize up and cease functioning. A few months into the project, Plug Power noticed for the first time that the meter had stopped registering. A close examination of the turbine meter showed that there was a significant amount of buildup on the meter and it was returned to the manufacturer for cleaning and remanufacturing. The manufacturer replaced the wetted components with titanium parts that were supposed to inhibit the buildup. The meter was reinstalled and failed about a month later. The time lag between failure and repair was on the order of 2 months. For a 1-year demonstration, that is a significant period of time. In all, the meter failed 3 times. Neither Plug Power nor the manufacturer anticipated this failure mode. Consideration has been given to potential future installations where a potable-water CHP system would be desired. Relocation of the BTU meter to a different point of the loop, water softening, and comprehensive water filtration among other measures will be addressed.
- Low overall efficiency – For the 3 months where complete thermal data exists there was low demand for CHP heat. This is typical for a domestic water application where heating is usually done in a batch mode and the majority of the time is spent maintaining the tank at temperature. The amount of heat reclamation by the CHP system is directly related to the hot water usage of the residents. During the mid-day and night hours, heat recovery was lowest. Alternatively, a CHP application with a large heat demand (like a swimming pool) would see much higher efficiencies.

11.0 Data Acquisition System

The GenSys^{TM} 5CS is designed to automatically send operational data (sampled every 10 minutes) once per day, via modem/dial-up connection, to Plug Power. Once at Plug Power, the data is entered into the fleet Quality Tracking Management System (QTMS) database. Furthermore, during every system shutdown, the unit automatically reports to Plug Power its status, error logs and high-speed data. The high-speed data is a packet of data-points taken at a much higher resolution (every second for the last 10 minutes). This information is used to track preventative maintenance items, troubleshoot failures, and dispatch field service technicians. Complete system operational data can also be downloaded directly from the machine by a trained service technician with a laptop and RS232 connection cable.

For this project, Plug Power decided to leverage the accessibility and security of the site to install a more comprehensive data collection system than the typical scenario described above. An extensive data monitoring and LAN setup with high-speed internet connection was installed to provide data with a resolution near to that in the Plug Power laboratory. Wireless network equipment relayed system data to a central server that transferred the data back to Plug Power. The result was high-quality, high-resolution data that helped Plug Power identify areas of improvement and develop a comprehensive baseline for performance across the fleet.

The data has been used to improve virtually every aspect of Plug Power's products and processes, from software and control upgrades to troubleshooting procedures and preventative maintenance forecasting. A schematic of the LAN setup can be seen in Appendix F.

12.0 Fuel Supply System

The GenSys™ 5CS fuel cell system is fueled by natural gas. Each four-unit building has five natural gas meters. Each of the four apartments and the common 80-gallon hot water tank are metered individually. The natural gas supply for the fuel cell systems was taken from downstream of the natural gas meter monitoring the hot water tank.

The GenSys™ 5CS natural gas requirements are:

- Constituency must be >90% methane.
- Sulfur content no greater than 15 ppm on a yearly average basis.
- Supply pressure: 4" – 11" water column.
- Maximum flow rate: 105,000 BTU/hr (~70 slm during startups).
- Nominal flow rate: 72,700 BTU/hr (~ 50 slm at 5kW setpoint).

13.0 Program Costs

An economic breakdown of the project and comparison to the initial economic analysis provides context to the program. Table 3 details the project cost breakdown. Appendix A provides the data for gas consumption and CHP production and Appendix F is the initial economic analysis performed at the beginning of the project.

As discussed in Section 10.0 – Thermal Recovery System, the thermal data from this project is incomplete. However, an estimate of thermal performance can be generated from the three months where complete data was obtained from the BTU meter at Building 21. The data in Appendix A shows that the months of May, October and November of 2003 produced complete thermal data. Averaging these values out for a full year, for four sites with eight systems, provides a conservative estimate of 181 MBTU or 1810 Therms.

Table 3: Economic Analysis

Final Cost Breakdown

	Qty	Total Cost
System Purchase Cost	8	$484,000.00
Warranty	8	$240,000.00
Installation Cost		$67,950.00
Performance Monitoring Cost		$2,764.00
Travel		$1,000.00
Decommissioning		$2,800.00
Fuel Usage (Therms)	22,300	
Fuel Rate ($/Therm)	$1.19	
Fuel Cost ($)		$26,537.00
Other		$14,813.00
Total Program Cost		**$839,864.00**

Avoided Cost

	Qty	Price*
Power Generated (kWhe)	164,395	$26,303
Heat Reclaimed (Therms)	1,810	$2,154
Avoided Cost ($)		**$1,920**
* Price of heat and power if purchased from the utility. *(NG = $1.19/Therm, Electric = $0.16/kWh)*		

Cost of Energy

	Electricity $/kWe	Heat $/kWt	CHP $/(kWe+kWt)
Fuel cost only	$0.16	$0.50	**$0.12**
Fuel + equipment/warranty cost	$4.57	$14.15	$3.45
Fuel + equipment/warranty + installation cost	$4.98	$15.43	$3.76
Total project cost	$5.11	$15.83	$3.86

Notes on Table 3:

- The final cost breakdown takes into consideration the removal of $6,800 in decommissioning expense. See Section 15 for details.

- The avoided cost is the difference between the amount of money that would have been paid if the power and heat were purchased from the utility minus the cost of the natural gas used. The avoided cost of $1,920 is lower than the initial forecast of $5,840. This difference is due to the reduced thermal recovery (estimated) for the program which is roughly 1/3 that assumed in the initial analysis.

- The cost of energy illustrates the impact of unit and installation cost on the effective rate of energy. With the total project cost factored in, a CHP rate of $3.86 / kW is realized. This is roughly a factor of 50 from where a commercial product needs to be in order to compete with the grid.

14.0 Milestones/Improvements

The demonstration at the Naval Support unit resulted in some significant milestones and product/process improvements. The most noteworthy of which are described below:

- Availability - The eight-system fleet finished the 1-year demonstration with an availability of over 95%. Two of the systems had final availability over 98%. These are significant improvements over previous demonstrations. A system that is 95% available is down for only 17.3 days per year.
- Fuel Cell Stack Life - A major increase in stack life was experienced during this demonstration. Additional testing is underway and details will be provided in an addendum to this report.
- CHP Design - This was the first Plug Power site where the CHP loop was used to directly heat potable/drinking water.
- Software – Software improvements enabled the systems to run longer time between failures and automated many processes that previously required manual intervention or a visit to the site. For example, addition of an auto-restart function and the ability for Plug Power to call into a system to check status. In earlier versions of software, communication was one-way only – the system would transmit data to Plug Power.
- Standby Capability – The GenSys™ 5CS is able to supply power during grid failures. During the major, northeast black-out in August 2003, all eight systems continued to operate in standby mode and supply power and domestic hot water to the apartments. The remaining 92 housing units at the complex were left in the dark.
- Data Monitoring – This was the first time a wireless LAN system was installed by Plug Power to send lab-quality data back to the engineering groups.
- Notification - Software was developed and installed on the Technical Support Line server to notify Plug Power personnel when a system had shut down via text messaging through a cell phone.

15.0 Decommissioning/Removal/Site Restoration

Two of the units at the NSU (B171 and B175) shall be allowed to run until July 30, 2004 in order for Plug Power to perform additional stack life testing. Plug Power de-commissioned the remaining six units after their demonstration period ended on 4/29/04. All eight systems will be removed no later than August 2, 2004. The sites will be left as-is after the eight units are removed, and the remaining site restoration work (piping, electrical, foundation and landscaping) shall be the responsibility of Plug Power and are no longer within the scope of this program.

In lieu of the cost of restoration of the NSU sites, Plug Power will install stockade fencing with a gate around each of the four fuel cell sites. If the cost of this fencing exceeds a total of $6,800, no further work shall be performed. If the cost of this fencing is less than $6,800, Plug Power will provide landscaping activities to restore areas of grass around the sites that have been damaged during the maintenance/operational phase of the demonstration. The cost of all activities (fencing and landscaping) will not exceed a total cost of $6,800.

An addendum to the final report shall be submitted to document the operation of the units during the extended run and to report on final site decommissioning activities.

16.0 Additional Research/Analysis

N/A

17.0 Conclusions/Summary

In conclusion, the FY02 PEM fuel cell demonstration at the Saratoga Springs NSU was a tremendous success. New availability benchmarks were set, increased system functionality was field-tested, product and process improvements were initiated and field support tools and techniques were implemented. The benefits of fuel cell technology and distributed power generation were evident during the major blackout that hit the northeast in August 2003. Out of 100 individual housing units affected, the eight fuel cell powered apartments were the only ones to have back-up power. This is a powerful symbol of the potential that this technology has to change the way the world generates, transmits and utilizes power.

Some of the key take-away points from this project are:

- Freeze protection and cold weather issues – It is intuitively obvious that an outdoor piece of equipment that uses water must have safeguards against freezing. Plug Power was able use the lessons learned from this project to improve the system design, field-support cold weather service techniques and internal test and verification procedures. All of these improvements will lesson the chance of freeze damage and allow the user to respond if in fact it does happen in the future. This type of learning cannot happen in the laboratory.

- Site Installation issues – Heavy ice build-up and similar weather related phenomena must be considered when selecting a site. Though must be given to the "what if….?" scenarios such as heavy rain, severe snowfall, water run-off paths, etc. Again, these are lessons only learned in the field and have a direct, positive impact not only during the installation phase, but long-term during operation.

- Potable water CHP installations – Validation of the potable water installation was an important step in the development of a CHP application profile. The ability to adapt to specific site conditions and integrate with different facility systems in critical to the future of fuel cell technology. The compatibility of equipment within this environment is important. This program suffered from a poor understanding of the tenacious nature of potable water and its desire to leave mineral deposits and calcium build-up on everything it touches. Future installations will avoid a repeat of this experience and new locations/modifications will be made to the BTU monitoring scheme used.

- Cost reduction – The typical GenSys™ 5CS fuel cell installation currently runs anywhere from $8000 upwards of $30,000 per system. There are always extenuating circumstances, but the fact remains – this is the real world and the ideal site does not exist. The NSU was fortunate to benefit from economy of scale and new interpretations of the NYS building codes that allow the use of potable water within the CHP loop. This interpretation allowed Plug Power to save approximately $1500 in auxiliary equipment per system and realize an installation cost of roughly $8500 each. This is still 3-4 times too expensive. Close interaction between the Customer, Field Support Group and Product Engineering is vital to capturing and incorporating the lessons learned from the field into future generation products.

  Long term, the only realistic way to reach a reasonably priced installation is through elimination of system requirements. For example:

  1. An indoor unit eliminates or reduces the need for:

a. Foundation preparation
b. Underground piping or fabrication of protective systems
c. Weatherproof support equipment (i.e. electrical enclosures)
d. Freeze issues
e. CHP loop equipment
f. Building penetrations
g. Etc.

2. A water independent system will eliminate the following scope of work:
    a. A water sample must be taken and sent to a lab for analysis.
    b. A pretreatment solution (if necessary) must be designed, procured and installed. Typically a softener or pre-filter package is required.
    c. Potable water (not always accessible) must be plumbed to the area.
    d. The DI panel must be mounted.
    e. A drain must be located (or installed) for the DI box.
    f. The multi-tube heat trace bundle must be run in a conduit with electrical heat trace.
    g. Terminations must be made on each end.
    h. The solenoid wire must be run inside a separate conduit with the communications wiring.
    i. The customer must use approximately 220 gallons per day of city water at 5kW and send 154 of that to the drain (not popular in drought areas).
    j. Etc.

<u>Appendix</u>

A. Monthly Performance Data
B. Maintenance Logs
C. Site Installation Drawing
D. Electrical Interconnection Drawing
E. CHP Installation Drawing
F. Data Acquisition – LAN Schematic
G. Initial Economic Analysis

Appendix A

Monthly Performance Data

Appendix B

Maintenance Logs

Plug Power Proprietary and Confidential Information

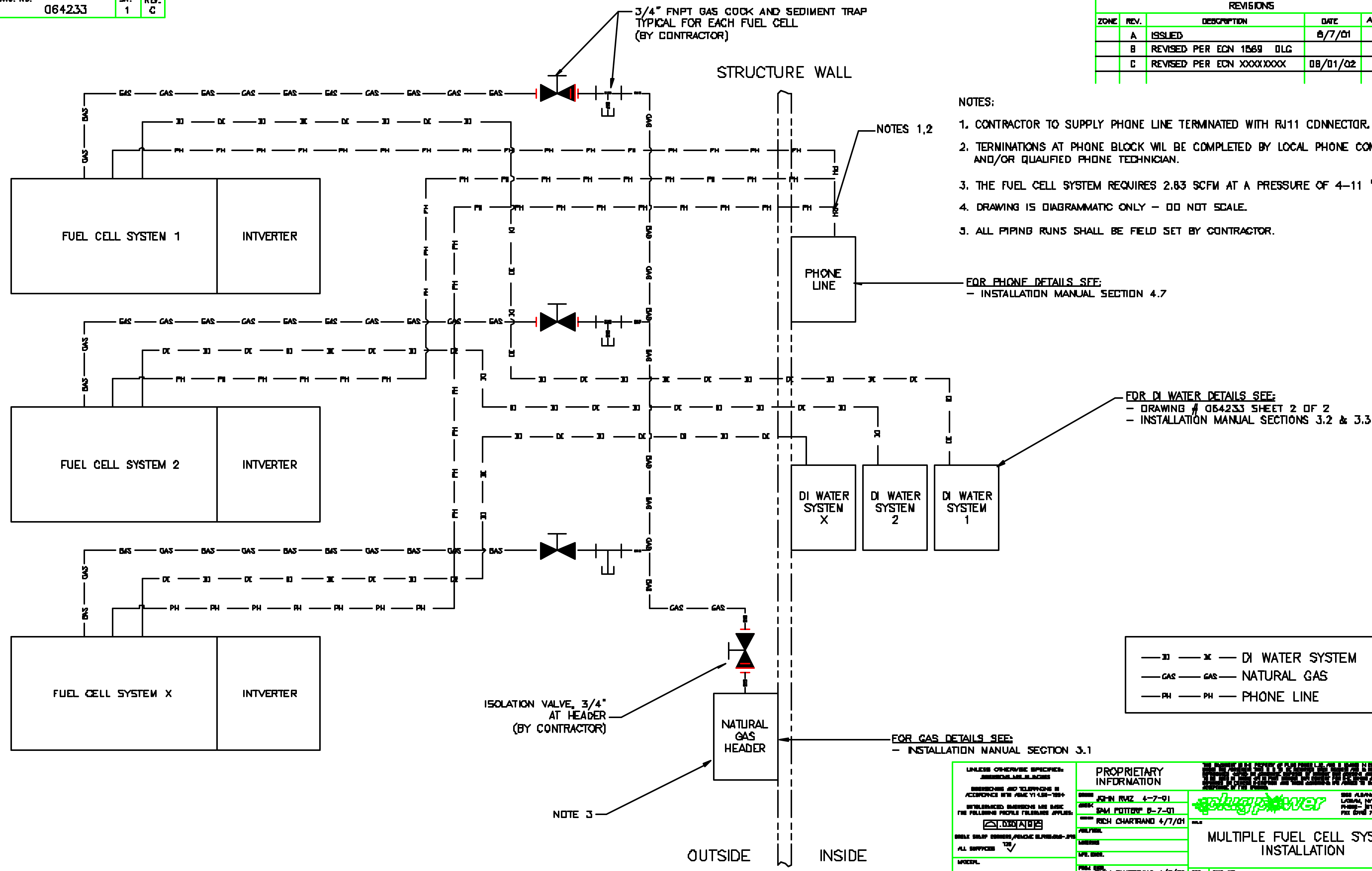
<u>Appendix C</u>

Site Installation Drawing

DWG. NO. 064233 | SH. 1 | REV. C

REVISIONS

ZONE	REV.	DESCRIPTION	DATE	APPROVED
	A	ISSUED	6/7/01	MCH
	B	REVISED PER ECN 1569 DLG		
	C	REVISED PER ECN XXXXXXXX	08/01/02	BCD



NOTES:

1. CONTRACTOR TO SUPPLY PHONE LINE TERMINATED WITH RJ11 CONNECTOR.
2. TERMINATIONS AT PHONE BLOCK WIL BE COMPLETED BY LOCAL PHONE COMPANY AND/OR QUALIFIED PHONE TECHNICIAN.
3. THE FUEL CELL SYSTEM REQUIRES 2.83 SCFM AT A PRESSURE OF 4–11 " w.c.
4. DRAWING IS DIAGRAMMATIC ONLY – DO NOT SCALE.
5. ALL PIPING RUNS SHALL BE FIELD SET BY CONTRACTOR.

UNLESS OTHERWISE SPECIFIED:

ALL SURFACES 125 √

MATERIAL

TREATMENT

PROPRIETARY INFORMATION

DRAWN	JOHN RUIZ 4-7-01
CHECK	SAM POTTERF 6-7-01
DESIGN	RICH CHARTRAND 4/7/01
ANALYTICAL	
MATERIALS	
MFG. ENGR.	
PROJ. ENGR.	RICH CHARTRAND 4/7/01
QUALITY CONTROL	
ISSUED	6-7-01

plugpower

TITLE: MULTIPLE FUEL CELL SYSTEM INSTALLATION

SIZE D | DWG. NO. 064233 | REV. C

SCALE NONE | SHEET 1 OF 2

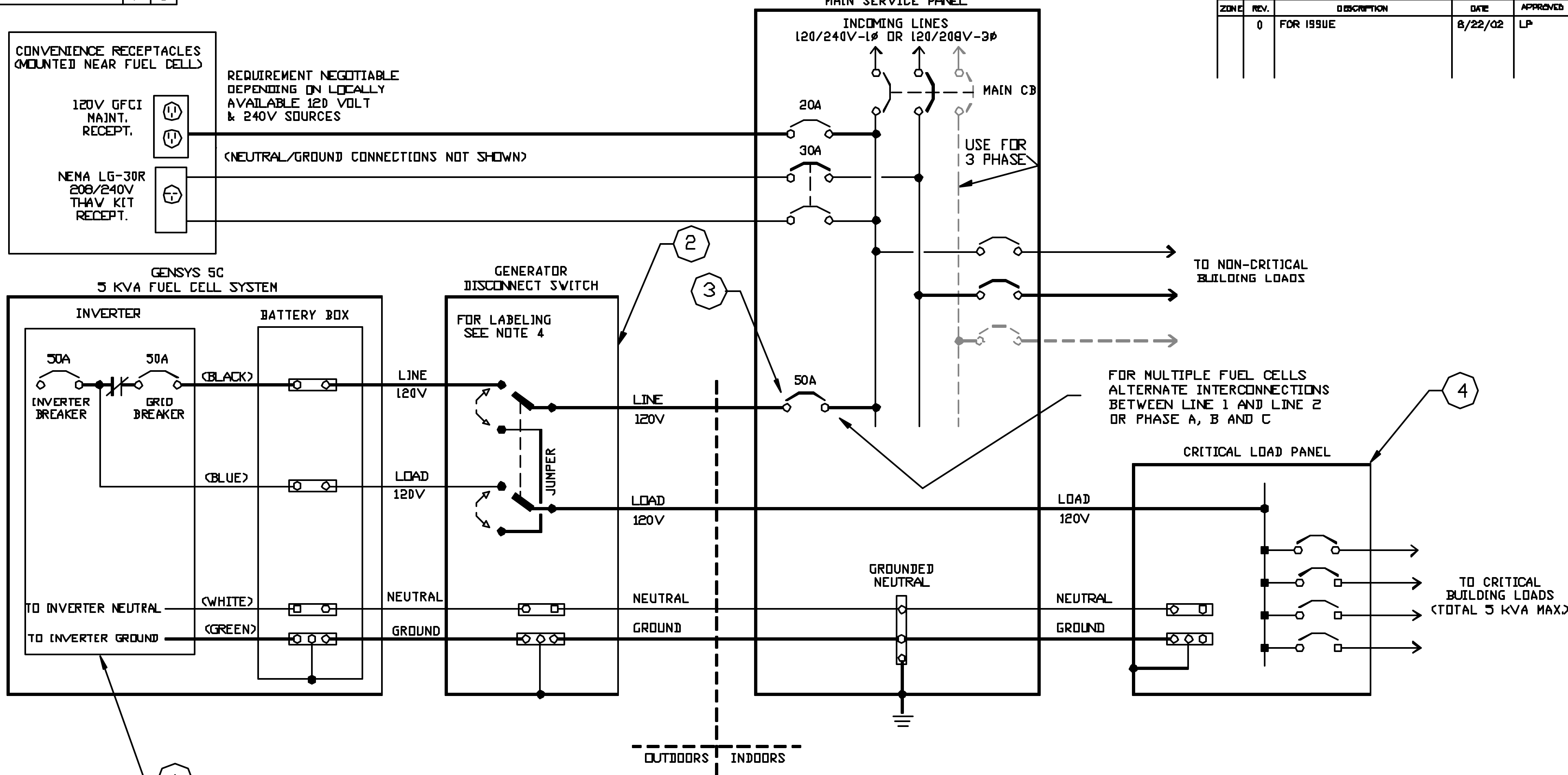
<u>Appendix D</u>

Electrical Interconnection Drawing

DWG. NO.	SH.	REV.
	1	0

REVISIONS

ZONE	REV.	DESCRIPTION	DATE	APPROVED
	0	FOR ISSUE	8/22/02	LP



ITEM	DESCRIPTION
1	INVERTER – PLUG POWER MP5000 – AUTOMATIC TRANSFER
2	GENERATOR DISCONNECT SWITCH – 60A DOUBLE POLE DOUBLE THROW, NON-FUSED – MANUAL TRANSFER
3	CIRCUIT BREAKER 50A SINGLE POLE -BOLTED ON
4	CRITICAL LOAD PANEL, LOAD CENTER

NOTES:

1. PERFORM ALL WORK IN ACCORDANCE WITH NATIONAL AND LOCAL CODES, STANDARDS, REGULATIONS AND LAWS INCLUDING NEC ARTICLE 692 FUEL CELL SYSTEMS.
2. CONDUIT RUNS AND ACTUAL CABLE ROUTING NOT SHOWN.
3. FOLLOW PROPER LOCK-OUT/TAG-OUT PROCEDURES.
4. LABLE GENERATOR DISCONNECT SWITCH POSITIONS: UP = "NORMAL/ON" DOWN = "MAINT. BYPASS/OFF"

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES

.030 A B C

ALL SURFACES ✓

PROPRIETARY INFORMATION

plug power

DESIGN L. POTTER 8/22/02

TITLE GenSys 5C Wiring Diagram
– NP 5000 INVERTER
– 120 V GRID PARALLEL & STAND-ALONE
– MANUAL BYPASS DISCONNECT SWITCH

SIZE D DWG NO. 068779 REV. 0

SCALE NONE SHEET 1 OF 1

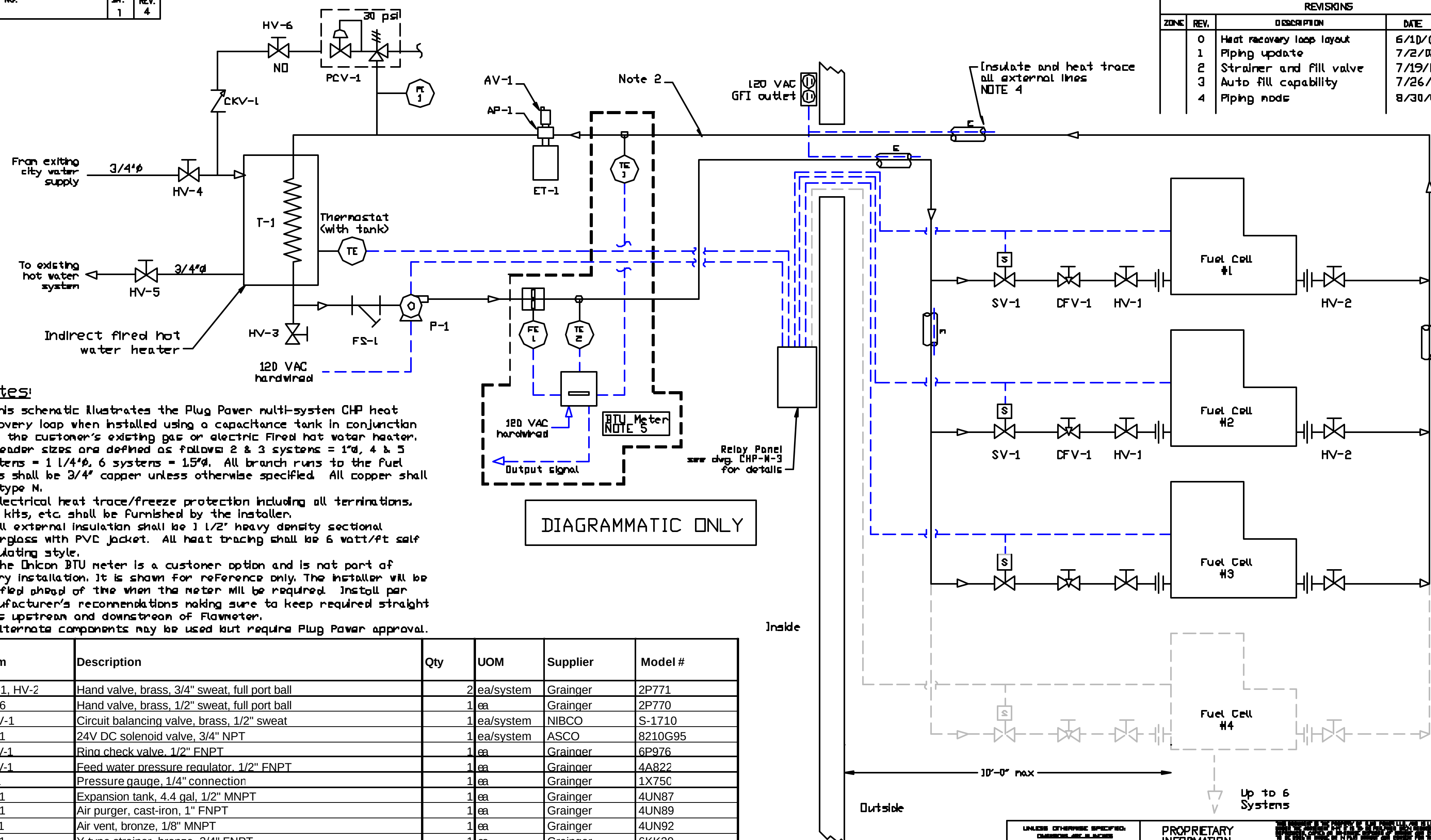
Appendix E

CHP Installation Drawing

DWG. NO.	SH.	REV.
	1	4

REVISIONS

ZONE	REV.	DESCRIPTION	DATE	APPROVED
	0	Heat recovery loop layout	6/10/02	BCD
	1	Piping update	7/2/02	BCD
	2	Strainer and fill valve	7/19/02	BCD
	3	Auto fill capability	7/26/02	BCD
	4	Piping mods	8/30/02	BCD



Notes:

1. This schematic illustrates the Plug Power multi-system CHP heat recovery loop when installed using a capacitance tank in conjunction with the customer's existing gas or electric fired hot water heater.
2. Header sizes are defined as follows: 2 & 3 systems = 1"ϕ, 4 & 5 systems = 1 1/4"ϕ, 6 systems = 1.5"ϕ. All branch runs to the fuel cells shall be 3/4" copper unless otherwise specified. All copper shall be type M.
3. Electrical heat trace/freeze protection including all terminations, end kits, etc. shall be furnished by the installer.
4. All external insulation shall be 1 1/2" heavy density sectional fiberglass with PVC jacket. All heat tracing shall be 6 watt/ft self regulating style.
5. The Onicon BTU meter is a customer option and is not part of every installation. It is shown for reference only. The installer will be notified ahead of time when the meter will be required. Install per manufacturer's recommendations making sure to keep required straight runs upstream and downstream of flowmeter.
6. Alternate components may be used but require Plug Power approval.

Item	Description	Qty	UOM	Supplier	Model #
HV-1, HV-2	Hand valve, brass, 3/4" sweat, full port ball	2	ea/system	Grainger	2P771
HV-6	Hand valve, brass, 1/2" sweat, full port ball	1	ea	Grainger	2P770
CFV-1	Circuit balancing valve, brass, 1/2" sweat	1	ea/system	NIBCO	S-1710
SV-1	24V DC solenoid valve, 3/4" NPT	1	ea/system	ASCO	8210G95
CKV-1	Ring check valve, 1/2" FNPT	1	ea	Grainger	6P976
PCV-1	Feed water pressure regulator, 1/2" FNPT	1	ea	Grainger	4A822
PI-1	Pressure gauge, 1/4" connection	1	ea	Grainger	1X750
ET-1	Expansion tank, 4.4 gal, 1/2" MNPT	1	ea	Grainger	4UN87
AP-1	Air purger, cast-iron, 1" FNPT	1	ea	Grainger	4UN89
AV-1	Air vent, brass, 1/8" MNPT	1	ea	Grainger	4UN92
FS-1	Y-type strainer, bronze, 3/4" FNPT	1	ea	Grainger	6KK29
P-1	Circulator pump				
	2-3 fuel cells	1	ea	Grainger	4PC87
	4-6 fuel cells	1	ea	Grainger	4PC84
HV-3	Drain valve, bronze, 3/4" MNPT	1	ea	Grainger	5E390
HV-4, HV-5	Hand valve, brass, 3/4" sweat, full port ball	2	ea	Grainger	2P771
Btu Meter	BTU meter with flowmeter (FE-1) and temp. elements (TE-1, TE-2)	0	ea	ONICON	100-F-1300-0.75
Relay Panel	Refer to dwg CHP-M-3 for details	1	ea	By Contractor	TBD
T-1	Indirect water heater	40	gal/system	By Contractor	TBD

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES

PROPRIETARY INFORMATION

DRAWN B. Davenport

DESIGN B. Davenport

TITLE CHP Heat Recovery Loop Multiple System Installation Schematic

SIZE	DWG. NO.	REV.
D	CHP-M-1	4

SCALE NONE

SHEET 1 of 3

Appendix F

Data Acquisition – LAN Schematic

2 ea. 4 port Hub
2 ea. 8 port Hub
8 ea. APC power strips
2 ea. 15ft. Extension cords

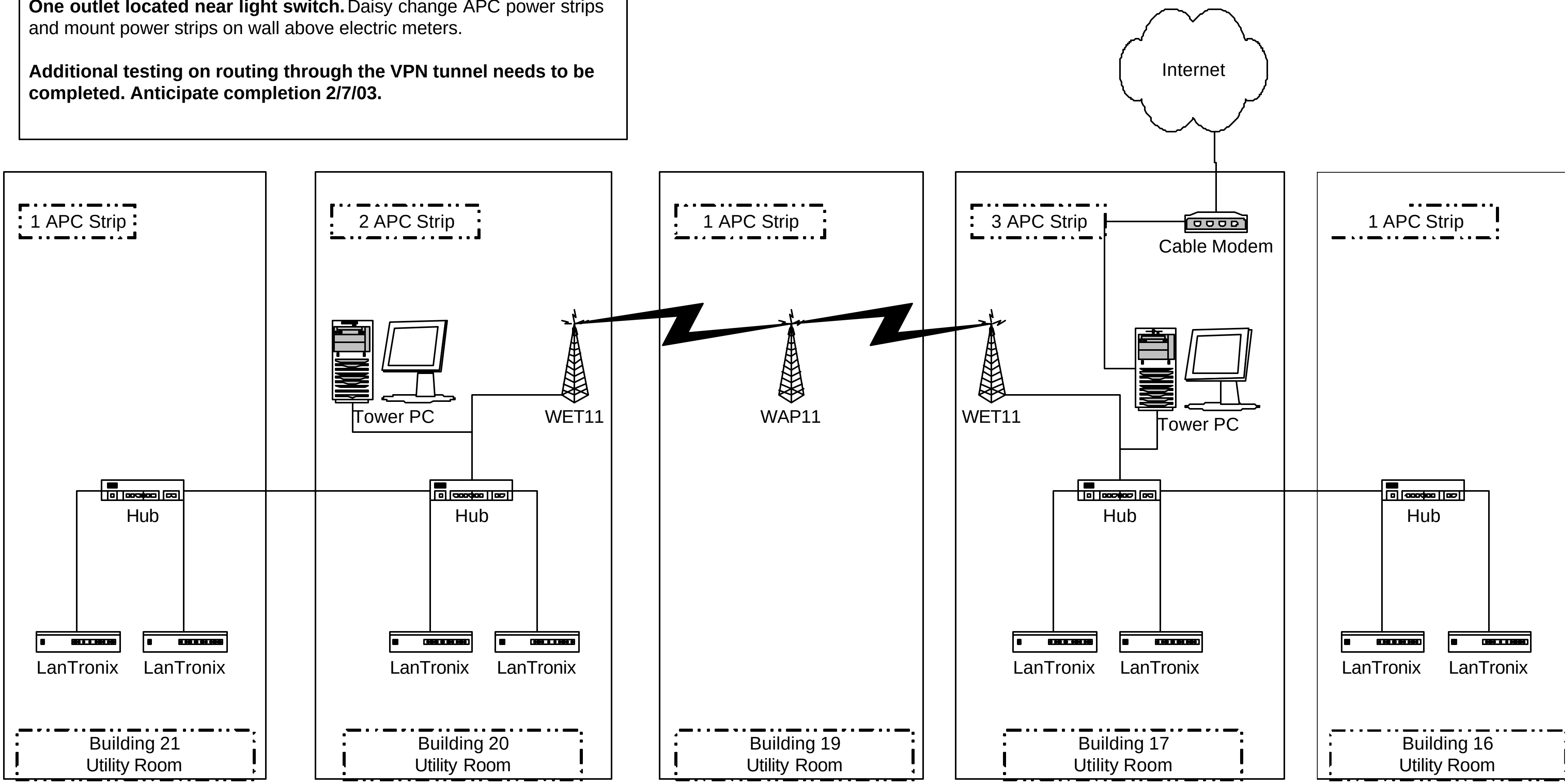
Outdoor CAT 5 cable between buildings 20-21 and 16-17 (run along the bottom of the siding / doors?)

Small computer table for buildings 17 and 20 (between water heater and furnace?)

Shelves for hubs / lantronix boxes / wireless equipment buildings 16,17,19, 20 & 21. (wall above electric meters?).

One outlet located near light switch. Daisy change APC power strips and mount power strips on wall above electric meters.

Additional testing on routing through the VPN tunnel needs to be completed. Anticipate completion 2/7/03.



Appendix G

Initial Economic Analysis

PROGRAM INITIAL ECONOMIC ANALYSIS

This program consists of the planning, installation, and operation of 8 Plug Power fuel cell systems at various locations supporting operations at the Naval Support Unit (NSU) – Quiet Harbor Complex, Saratoga Springs, NY. The NSU is serviced by Niagara Mohawk for both its electricity and natural gas supply.

The NSU Housing Department (Mike Cyktich – PWO) has supplied utility billing information for FY2002. The rates below were calculated by dividing the total electrical/gas cost by the total number of kW-hrs/therms used respectively. The rates, therefore, include delivery charges, taxes and other fees included within the Niagara Mohawk cost structure and will allow a more realistic economic analysis.

- Electrical = $0.16/kW-hr
- Natural Gas = $1.19/therm

The system gas usage rate is based upon the nominal Plug Power Lower Heating Value for natural gas of 804 kJ/mol and an average beginning of life (BOL) electrical efficiency of 24.8%. This efficiency is calculated using a weighted average of the system efficiencies at the different set points.

- System natural gas usage rate = 0.138 therms/kW-hr

The program run hours is based on 8 systems operating with a total availability of 90% for the one-year life of the program:

- Program run hours = 24 hrs X 365 days X 0.90 X 8 = 63,072 hrs.

The program number of kilowatt-hours (electrical) produced is based on a system power set point of 2.5 kW for the program run hours above:

- Program $kW\text{-}hr_e$ = 2.5 kW X 63,072 hrs. = 157,680 $kW\text{-}hr_e$

The program number of therms claimed by the customer is based on a system power set point of 2.5 kW for the program run hours above and an overall system efficiency of 50%. Since overall efficiency is based on utilizing the “waste” heat from the fuel cell, the therms claimed by the customer will vary depending on hot water demand:

- Program therms = 2.5 kW / 0.248 X [0.5 – 0.248] X 63,072 hrs X 0.03412 therms/kW-hr = 5466.8 therms

The program number of therms of natural gas consumed by the fuel cells is based on the usage rate multiplied by the number of program kW-hrs above:

- Program therms consumed = 157,680 kW-hrs X 0.138 therms/kW-hr = 21,759.8 therms

The program total cost of natural gas is based on the number of therms consumed multiplied by the cost per therms:

- NG cost = 21,759.8 therms X $1.19/therm = $25,894.16

The equivalent cost of the fuel cell electricity and heat if purchased from Niagara Mohawk is based on the number of kilowatt-hours and therms produced by the systems multiplied by Niagara Mohawk's rate:

- Electrical cost = 157,680 kW-hr X $0.16/kW-hr = $25,228.80

- Thermal cost = 5466.8 Therms X $1.19/therm = $6,505.49

The projected total energy savings for the program by using system-generated electricity and heat instead of purchasing it from Niagara Mohawk is:

- Avoided cost = $25,228.80 + $6,505.49 – $25,894.16 = **$5,840.13 total**

- Avoided cost per residence = $5,840.13 / 8 = $730.02

Suggested Format for PEM Fuel Cell Performance Data

System Number:	SU01B000000168		**Commission Date:**	4/29/2003	**Site Location(City,State):** Saratoga, N.Y.
Site Name:	Naval Support Unit	Bldg 21	**Fuel Cell Type:**	GenSys 5CS	
Fuel Type:	Natural Gas		**Maintenance Contractor:**	Plug Power LLC.	
Higher Heating Value:	804.7 kJ/l		**Local Fuel Cost per therm:**	$1.19	
Capacity kW	5		**Local Electricity Cost per kW:**	$0.16	

Month	Run Time (Hours)	Time in Period (Hours)	Availability (%)	Energy Produced (kWe-hrs AC)	Output Setting (kW)	Average Output (kW)	Capacity Factor (%)	Fuel Usage, LHV (BTUs)	Fuel Usage (SCF)	Electrical Efficiency (%)	Thermal Heat Recovery (BTUs)	Heat Recovery Rate (BTUs/hour)	Thermal Efficiency (%)	Overall Efficiency (%)	Number of Scheduled Outages	Scheduled Outage Hours	Number of Unscheduled Outages	Unscheduled Outage Hours
insert month	*insert operating hours*	*insert hours in month*	**1*	*insert produced energy*	*insert output setting*	**2*	**3*	*insert fuel consumption*	*insert fuel consumption*	**4*	*insert heat recovery*	**5*	**6*	**7*	*insert value*	*insert value*	*insert value*	*insert value*
May,2003	719.8	744	97%	1818.0	2.5	2.53	48.87%	2.22E+07	2.20E+04	27.91%	3354000	4659.8	15.09%	43.00%	0	0	1	24.2
June,2003	702.2	720	98%	1862.6	2.5	2.65	51.74%	2.52E+07	2.49E+04	25.28%	0	0.0	0.00%	25.28%	2	6.3	2	11.5
July,2003	682.0	744	92%	1727.0	2.5	2.53	46.42%	2.38E+07	2.35E+04	24.76%	0	0.0	0.00%	24.76%	2	26	2	36
August,2003	711.5	744	96%	1824.0	2.5	2.56	49.03%	2.30E+07	2.28E+04	27.05%	0	0.0	0.00%	27.05%	1	2.5	2	30
September, 2003	720.0	720	100%	1806.0	2.5	2.51	50.17%	2.19E+07	2.16E+04	28.20%	8147000	11315.3	37.27%	65.47%	0	0	0	0
October, 2003	744.0	744	100%	1850.6	2.5	2.49	49.75%	2.32E+07	2.30E+04	27.20%	4091000	5498.7	17.61%	44.81%	0	0	0	0
November, 2003	720.0	720	100%	1781.0	2.5	2.47	49.47%	2.38E+07	2.35E+04	25.57%	3958000	5497.2	16.65%	42.22%	0	0	0	0
December, 2003	698.8	744	94%	1816.0	2.5	2.60	48.82%	2.15E+07	2.12E+04	28.89%	0	0.0	0.00%	28.89%	0	0	1	45.2
January, 2004	657.3	744	88%	1565.0	2.5	2.38	42.07%	2.09E+07	2.07E+04	25.55%	0	0.0	0.00%	25.55%	0	0	1	86.7
February, 2004	662.4	696	95%	1639.1	2.5	2.47	47.10%	2.83E+07	2.79E+04	19.80%	0	0.0	0.00%	19.80%	0	0	3	33.6
March, 2004	608.6	744	82%	1403.0	2.5	2.31	37.72%	2.40E+07	2.37E+04	19.99%	0	0.0	0.00%	19.99%	0	0	3	135.4
April, 2004	713.0	720	99%	1801.8	2.5	2.53	50.05%	2.16E+07	2.13E+04	28.52%	0	0.0	0.00%	28.52%	0	0	1	7
			#DIV/0!			#DIV/0!	#DIV/0!		0.00E+00	#DIV/0!		#DIV/0!	#DIV/0!	#DIV/0!				
			#DIV/0!			#DIV/0!	#DIV/0!		0.00E+00	#DIV/0!		#DIV/0!	#DIV/0!	#DIV/0!				
			#DIV/0!			#DIV/0!	#DIV/0!		0.00E+00	#DIV/0!		#DIV/0!	#DIV/0!	#DIV/0!				
Running Totals																		
	Total Run Time	**Total Hours in Period**	**Total Availibility (*8)**	**Total Energy Produced**	**Average Output Setting**	**Total Average Output (*9)**	**Total Capacity Factor (*10)**	**Total Fuel Usage**	**Total Fuel Usage**	**Average Electrical Efficiency (*11)**	**Total Thermal Heat Recovery**	**Average Heat Recovery Rate (*12)**	**Average Thermal Efficiency (*13)**	**Average Overall Efficiency (*14)**	**Total Outages**	**Total Hours**	**Total Outages**	**Total Hours**
	8339.6	8784	95%	20894.1	2.5	2.51	47.57%	2.79E+08	276080.1247	25.54%	19550000	2344.2	7.00%	32.54%	5	34.8	16	409.6

Naval Support Unit (NSU) – Saratoga Springs, NY
PEM Fuel Cell Demonstration Program
Maintenance Logs

May 2003 - Monthly Report

Pursuant to Contract # DACA42-03-C-0005

Section 1.0 Summary/Update

May 2003 represents the 1st month of operation for the eight Plug Power fuel cell systems installed at the Naval Support Unit – Saratoga Springs, NY. The official commissioning date of the systems is April 29, 2003.

Overall, the fuel cell systems experienced an availability of 94.7% for the month and a base electrical efficiency of 28.7%. Thermal performance is available for building 21 – systems B168 and B169. The thermal monitoring device measures the combined heat transfer from the two fuel cells into the site host's water system. This total was divided among the two systems based upon total system electrical output. The data reflects fairly low thermal efficiencies – which is expected as the ambient temperature rises. As we continue to gather data, a more detailed analysis of thermal performance will be developed.

May ended with all of the fuel cell systems operational and running smoothly.

Section 2.0 Service History

The following is a summary of the major maintenance issues experienced during the month of May 2003:

A majority of the failure modes experienced by the fuel cell systems this month were due to water supply issues. For example, in one case the ATO (Anode Tail-gas Oxidizer) overheated after the deionized (DI) water supply was restricted to the reformer. The ATO is the portion of the reformer that takes any unused hydrogen from the stack and converts it to water in the presence of a catalyst. DI water is required within the fuel cell as part of the steam reformation process. Plug Power provides a filter assembly with each unit that converts city/tap water into DI water for the system. The water quality at the NSU was slightly out of specification for the filter assembly and resulted in premature failure/clogging of the cartridges. Pre-filters were installed to increase life and a preventative maintenance schedule is being developed to proactively change out the filters to avoid nuisance trips of the fuel cells.

On May 7, 2003 there was a power outage at the NSU. One system had difficulty transferring to stand-by capability and shut down - the root cause is under investigation. Furthermore, the data monitoring system that was installed to provide near laboratory quality data was plugged into an outlet in the mechanical room. This portion of the building is not supported by the standby capability of the fuel cell and as a result, the computers went down. Work is underway to investigate the possibility of connecting the data collection system to the fuel cells in order to maintain a steady supply of power and flow of data. The system information from this period was retrieved manually from the fuel cells.

June 2003 - Monthly Report

Pursuant to Contract # DACA42-03-C-0005

Section 1.0 Summary/Update

June 2003 represents the 2nd month of operation for the eight Plug Power fuel cell systems installed at the Naval Support Unit – Saratoga Springs, NY. The official commissioning date of the systems is April 29, 2003.

Overall, the fuel cell systems experienced a monthly availability of 98.1% with a base electrical efficiency of 23.2% (HHV). Thermal performance is available for building 21 – systems B168 and B169. The thermal monitoring device measures the combined heat transfer from the two fuel cells into the site host's water system. This total was divided (weighted) among the two systems based upon total system electrical output. The data reflects fairly low thermal efficiencies – which is expected during the summer months when heat demand is low.

June ended with all of the fuel cell systems operational and running smoothly.

Section 2.0 Service History

The following is a summary of the major maintenance issues experienced during the month of May 2003:

Scheduled Maintenance

Software: New software (version 1.23) was loaded on all eight fuel cell systems during June. The new software contained improved control algorithms for better, more robust reformer operation.

Water Filters: DI water is required within the fuel cell as part of the steam reformation process. Plug Power provides an RO (reverse osmosis) filter assembly with each unit to convert city/tap water into DI water for the system. The water quality at the NSU was slightly out of specification for the filter assembly and resulted in premature failure/clogging of the cartridges. All RO filters were changed and pre-filters were installed to increase life. A preventative maintenance schedule was developed to proactively change out the filters and avoid nuisance trips of the fuel cells.

Air Inlet Filters: High pollen levels, grass clippings and similar airborne particulate matter were clogging the air inlet filters on a majority of the systems. These were cleaned and a preventative maintenance schedule was developed to keep the filters free from debris and avoid unnecessary shutdowns.

Unscheduled Shutdowns

PROX valves: Three systems shut down for issues due to malfunctioning PROX valves. These valves are responsible for adding air to the section of the fuel processor that reduces (scrubs) the CO and converts it into CO2. Root cause and a resolution is being worked with the vendor. New valves were certified by Plug Power and installed into the systems prior to restart.

July 2003 - Monthly Report

Pursuant to Contract # DACA42-03-C-0005

Section 1.0 Summary/Update

July 2003 represents the 3rd month of operation for the eight Plug Power fuel cell systems installed at the Naval Support Unit – Saratoga Springs, NY. The official commissioning date of the systems is April 29, 2003.

Overall, the fuel cell systems experienced a monthly availability of 95.4% with a base electrical efficiency of 22.5% (HHV). Thermal performance is unavailable for building 21 – systems B168 and B169. The thermal monitoring device has had a host of problems with the integrated flow meter. The manufacturer has been engaged to work a solution and a modified flow meter is expected to be in place by the end of August. A more detailed description of the root cause and corrective actions is being developed and will be included in the August report.

July ended with all of the fuel cell systems operational and running smoothly.

Section 2.0 Service History

The following is a summary of the major maintenance issues experienced during the month of July 2003:

Batteries: During normal system monitoring, it was noticed that system B168 was charging batteries more often then normal. During a subsequent shutdown and battery load test on July 10, 2003 it was found that one battery was bad. It was determined that the failure was due to pre-installation freezing.

Methane Trips: System B168 experienced methane sensor trips on July 14 and 28, 2003. A blown fuse that supplies power to the sensors was found on the Power Distribution Board and replaced.

Electrical failure: System B175 shut down on July 23, 2003 due to a failed DC-DC converter on the PDB board. This resulted in system-wide electrical failures in other boards and motors. The converter was replaced and root-cause is under investigation.

August, 2003 - Monthly Report

Pursuant to Contract # DACA42-03-C-0005

Section 1.0 Summary/Update

August 2003 represents the 4th month of operation for the eight Plug Power fuel cell systems installed at the Naval Support Unit – Saratoga Springs, NY. The official commissioning date of the systems is April 29, 2003.

Overall, the fuel cell systems experienced a monthly availability of 97.25% with a base electrical efficiency of 22.003% (HHV). Thermal performance is unavailable for building 21 – systems B168 and B169. The thermal monitoring device has had a host of problems with the integrated flow meter. The manufacturer has modified the flow meter and it was reinstalled on 8/29/03. The BTU meter reading at that time was 006800.

August ended with all of the fuel cell systems operational and running smoothly.

Section 2.0 Service History

The following is a summary of the major maintenance issues experienced during the month of August 2003:

Methane Trips: Systems B168 and B175 experienced methane sensor trips on August 3rd, 11th,and 15th, 2003. We have been unable to attend the root cause of these shutdowns. No leaks where detected after restarting.

Software issue: System B-176 shutdown due to a Humidifier Top Low Temp. This shutdown was preceded by a Fuel Cell Stack cell trip. The root cause of this problem can be traced to the SARC software not responding quickly enough to the Cell trip. The corrective action has been implemented in the next Revision of software due to be released in October.

Prox Catalyst air Valve: System B-168 was proactively shutdown to replace a malfunctioning Prox valve that was causing the reformer to make poor quality gas.

September, 2003 - Monthly Report

Pursuant to Contract # DACA42-03-C-0005

Section 1.0 Summary/Update

September 2003 represents the 5th month of operation for the eight Plug Power fuel cell systems installed at the Naval Support Unit – Saratoga Springs, NY. The official commissioning date of the systems is April 29, 2003.

Overall, the fuel cell systems experienced a monthly availability of 96.5% with a base electrical efficiency of 24.1% (HHV). Thermal performance is now available for building 21 – systems B168 and B169. September ended with all of the fuel cell systems operational and running smoothly.

Section 2.0 Service History

The following is a summary of the major maintenance issues experienced during the month of August 2003:

Nuisance Trips: System B-171 has had a few CPO Low temperature shutdowns. As of yet we have been unable to determine the root cause.

Humidification: We replaced a Humidification Level Sensor in system B-169 that was reading incorrectly.

Prox Catalyst air Valve: System B-169 was proactively shutdown to replace a malfunctioning Prox valve that was causing the reformer to make poor quality gas.

Maintenance: Maintenance on the air inlet screens/filters was performed on all eight systems.

Water purification: Several RO water filters were replaced due to low flow.

October, 2003 - Monthly Report

Pursuant to Contract # DACA42-03-C-0005

1.0 Summary/Milestones

October was a good month with only one system shutdown for an overall availability of 98.2%. All units ran at 2.5kW and the 6th month of operation was completed.

2.0 Scheduled Outages

System Number: SU01B000000175
Outage Date(s):10/06/03
Duration: 5 hours

Description: The system was shut down to replace a sticking PROX valve that was causing unnecessary stack recovery activities. At this time, the enthalpy wheel was changed out. Data analysis showed that the cathode inlet temperature was slightly out of range – visual inspection showed that the enthalpy wheel had signs of degradation. This is a normal failure mode for the wheel.

System Number: SU01B000000174
Outage Date(s):10/30/03
Duration: 6 hours

Description: The system was experiencing low cell voltages that caused the unit to enter an almost constant state of stack recovery. The stack was replaced.

System Number: SU01B000000173
Outage Date(s):10/30/03
Duration: 27.6 hours

Description: System was shut down because low cell voltages had the unit in constant stack recovery. The stack was replaced and upon restart, it was noticed that the there were still issues with cell performance. The enthalpy wheel was inspected and showed signs of degradation. The e-wheel was replaced and the unit restarted.

3.0 Unscheduled Outages

System Number: SU01B000000173
Outage Date(s):10/11/03
Duration: 6 hours

Description: System shut down due to low cell trips. The unit was restarted without failure and it was noted that the stack needs a replacement soon.

System Number: SU01B000000176
Outage Date(s):10/11/03
Duration: 6 hours

Description: System shut down due to low cell trips. The unit was restarted without failure and it was noted that the stack needs a replacement soon.

System Number: SU01B000000173
Outage Date(s):10/20/03
Duration: 6 hours

Description: System shut down due to low DI water supply. The filters were replaced earlier in the month so a more detailed look at the water supply was conducted. No trouble was found and the filter panel was making water within specifications. The unit was restarted.

4.0 Component Replacement

System Number: SU01B000000175
Replaced Component: PROX valve
Date Replaced: 10/6/03
Total Component Run Hours: 3463

Description: The system was shut down to replace a sticking PROX valve that was causing unnecessary stack recovery activities. This is a known failure mode with this valve and is being addressed with the manufacturer.

System Number: SU01B000000175
Replaced Component: Enthalpy Wheel
Date Replaced: 10/6/03
Total Component Run Hours: 3463

Description: The system was shut down to replace the enthalpy wheel. With use, the core material in the wheel will degrade and impact overall system performance. As part of the 12,000 kWh maintenance package, this wheel is routinely replaced. The system in question was approaching this mark and enthalpy wheel replacement was already planned.

System Number: SU01B000000173
Replaced Component: Enthalpy Wheel
Date Replaced: 10/30/03
Total Component Run Hours: 4345

Description: The system was shut down to replace the enthalpy wheel. With use, the core material in the wheel will degrade and impact overall system performance. As part of the 12,000 kWh maintenance package, this wheel is routinely replaced. The system in question was approaching this mark and enthalpy wheel replacement was already planned.

System Number: SU01B000000173
Replaced Component: Fuel cell stack
Date Replaced: 10/30/03
Total Component Run Hours: 4728

Description: The fuel cell stack was replaced.

System Number: SU01B000000174
Replaced Component: Fuel cell stack
Date Replaced: 10/30/03
Total Component Run Hours: 4832

Description: The fuel cell stack was replaced.

5.0 Other Comments

During the month of October, the reverse osmosis (RO) and carbon filters were replaced for four systems. These filters are a regular maintenance item and do not require the unit to be shut down when changed. This external assembly is responsible for converting city water to deionized (DI) water for the fuel cell. The system numbers and date of filter change are as follows:

- SU01B000000170 – 10/10/03
- SU01B000000173 – 10/10/03
- SU01B000000174 – 10/10/03
- SU01B000000176 – 10/07/03

November, 2003 - Monthly Report

Pursuant to Contract # DACA42-03-C-0005

1.0 Summary/Milestones

November was another good month with an overall availability of 95.2%. Two systems were shut down to replace a component that Plug Power has not seen fail in over 350 field units – the LTS pan. Environmental factors are being analyzed to determine the cause of corrosion and failure of these two parts. All units ran at 2.5kW and the 7th month of operation was completed.

2.0 Scheduled Outages

System Number: SU01B000000171
Outage Date(s):11/20/03
Duration: 26.4 hours

Description: The system was shut down to replace a corroded LTS pan. The source of corrosion and means of prevention is under analysis.

3.0 Unscheduled Outages

System Number: SU01B000000173
Outage Date(s):11/8/03
Duration: 77.5 hours

Description: System shut down due to an ATO flashback. A new DI water level sensor, humidifier pump and SARC board were installed. The failure was a control issue resulting from a failure in the SARC board. Rot cause is under analysis. The pump and sensor were found to be trending out of specification and replaced as a precaution.

System Number: SU01B000000175
Outage Date(s):11/9/03
Duration: 12 hours

Description: System shut down due to a high exhaust temperature. The ATO blower failed. Troubleshooting identified a failure of the motor control board. The board was replaced and unit restarted.

System Number: SU01B000000175
Outage Date(s):11/20/03
Duration: 8.5 hours

Description: System shut down due to a high exhaust temperature. The data collection system was experiencing problems and the shut down data was lost. This is a recurrence of the failure above and is under further investigation. The system was restarted.

System Number: SU01B000000170
Outage Date(s):11/17/03
Duration: 97 hours

Description: System shut down because of a gas leak that caused an ATO flashback. The air TSI flow meter, PROX air valve and ATO can were replaced. The leak was fixed and this opportunity was used to replace the stack and a corroded LTS pan. The system was restarted.

System Number: SU01B000000174
Outage Date(s):11/22/03
Duration: 55.8 hours

Description: System shut down due to low DI water supply. The DI filters in the external panel assembly were replaced and the unit was restarted.

4.0 Component Replacement

System Number: SU01B000000171
Replaced Component: LTS Pan
Date Replaced: 11/20/03
Total Component Run Hours: 4433

Description: The LTS pan had rusted through and was replaced.

System Number: SU01B000000170
Replaced Component: LTS Pan
Date Replaced: 11/17/03
Total Component Run Hours: 4665

Description: The LTS pan had rusted through and was replaced.

System Number: SU01B000000171
Replaced Component: Air TSI Flow Meter
Date Replaced: 11/17/03
Total Component Run Hours: 4665

Description: The flow meter was suspected to contribute to the gas leak that originally shut this unit down and was replaced as a preventative measure.

System Number: SU01B000000171
Replaced Component: PROX Air Valve
Date Replaced: 11/17/03
Total Component Run Hours: 4665

Description: The PROX Air Valve was suspected to contribute to the gas leak that originally shut this unit down and was replaced as a preventative measure.

System Number: SU01B000000171
Replaced Component: ATO Can
Date Replaced: 11/17/03
Total Component Run Hours: 4665

Description: The ATO can was suspected to contribute to the gas leak that originally shut this unit down and was replaced as a preventative measure.

System Number: SU01B000000170
Replaced Component: Stack
Date Replaced: 11/17/03
Total Component Run Hours: 4473

Description: The stack was replaced.

System Number: SU01B000000173
Replaced Component: DI Water Level Sensor
Date Replaced: 11/8/03
Total Component Run Hours: 4540

Description: Component inspected during an unplanned shutdown and found to be trending out of specification. Replaced as a preventative measure.

System Number: SU01B000000173
Replaced Component: Humidifier Pump
Date Replaced: 11/8/03
Total Component Run Hours: 4540

Description: Component inspected during an unplanned shutdown and found to be trending out of specification. Replaced as a preventative measure.

System Number: SU01B000000173
Replaced Component: SARC Board
Date Replaced: 11/8/03
Total Component Run Hours: 4540

Description: The stack and reformer control (SARC) board was replaced due to a failure and resulting ATO flashback. Root-cause is under analysis.

5.0 <u>Other Comments</u>

During the month of November, the reverse osmosis (RO) and carbon filters were replaced for three systems. These filters are a regular maintenance item and do not require the unit to be shut down when changed. This external assembly is responsible for converting city water to deionized (DI) water for the fuel cell. The system numbers and date of filter change are as follows:

- SU01B000000169 – 11/14/03
- SU01B000000170 – 11/14/03
- SU01B000000175 – 11/26/03

December, 2003 - Monthly Report

Pursuant to Contract # DACA42-03-C-0005

1.0 Summary/Milestones

December was another good month with an overall availability of 98.1%. All units ran at 2.5kW and the 8th month of operation was completed.

2.0 Scheduled Outages

System Number: SU01B000000176
Outage Date(s):12/23/03
Duration: 4 hours

Description: The system was experiencing low stack output due to a degradation of the upper cells. The unit was shutdown and the stack replaced.

3.0 Unscheduled Outages

System Number: SU01B000000168
Outage Date(s):12/1/03
Duration: 45.2 hours

Description: System shut down due to the inverter not exporting AC power. During the course of troubleshooting, a solenoid valve in the fuel delivery system, the air flow meter and SARC board were replaced. These were later found not to have contributed to the original shutdown event. Rather, failures during subsequent start-up attempts identified that the components were affected by the cold weather (extended down-time) and were operating outside of specifications. A temperature offset in the Prox set-points improved gas quality and remedied the situation. Data analysis is ongoing to determine the reason for the set-point change requirement.

System Number: SU01B000000169
Outage Date(s):12/29/03
Duration: 9.2 hours

Description: System shut down due to an internal communication loss. Power to the system was cycled and the unit restarted without incident.

System Number: SU01B000000171
Outage Date(s):12/23/03

Duration: 9.5 hours

Description: System shut down due to a cathode inlet low temperature fault. The condensate drain on the enthalpy wheel was plugged. A common failure mode is degradation of the enthalpy wheel core material. The wheel was replaced and the unit restarted.

System Number: SU01B000000175
Outage Date(s):12/2/03
Duration: 47.1 hours

Description: System shut down due to a failure of the humidifier pump. The pump and motor control board were replaced and the unit restarted.

4.0 Component Replacement

System Number: SU01B000000168
Replaced Component: Solenoid 9
Date Replaced: 12/2/03
Total Component Run Hours: 5024

Description: The valve (fuel delivery system) was not reacting to control signals properly.

System Number: SU01B000000168
Replaced Component: Air TSI (flow meter)
Date Replaced: 12/2/03
Total Component Run Hours: 5024

Description: The flow meter was reading out of calibration and providing false readings to the control system.

System Number: SU01B000000168
Replaced Component: SARC board (control board)
Date Replaced: 12/2/03
Total Component Run Hours: 5024

Description: The control board was replaced during troubleshooting and found to be within specs. The replacement was left in the machine to avoid another shutdown to reinstall the original.

System Number: SU01B000000171
Replaced Component: Enthalpy wheel
Date Replaced: 12/23/03
Total Component Run Hours: 5438

Description: The enthalpy wheel was replaced due to degradation of the core material.

System Number: SU01B000000176
Replaced Component: Stack
Date Replaced: 12/23/03
Total Component Run Hours: 5488

Description: The stack was replaced.

System Number: SU01B000000175
Replaced Component: Humidifier pump and motor control board (MCB)
Date Replaced: 12/2/03
Total Component Run Hours: 4806

Description: Components were not operating/responding to control signals from the main control board and were replaced.

5.0 <u>Other Comments</u>

The BTU meter measuring heat transfer for systems B168 and B169 failed and no thermal readings are available for the month. This same phenomenon has been experienced at the West Point fuel cell sites. The root cause is the aggressive nature of potable water and the constant introduction of deposit building material into the CHP loop. The result is heavy build-up on the flow meter moving parts. This eventually causes the meter to seize. A replacement meter is being installed and more frequent inspections of the loop will be made.

January, 2004 - Monthly Report

Pursuant to Contract # DACA42-03-C-0005

1.0 <u>Summary/Milestones</u>

January was a poor month with an overall availability of 80.3%. All units ran at 2.5kW and the 9th month of operation was completed. A new failure mode was discovered when most of the NSU systems experienced Radiator fan motor malfunctions. Root cause was attributed to improper specification of internal parts on the motor control board. It was determined that some of the components on the board are unreliable in extreme cold weather conditions. As a containment action, software adjustments were made. The Plug Power engineering department is currently developing a permanent repair.

2.0 <u>Scheduled Outages</u>

System Number: SU01B000000175
Outage Date(s): 1/05/04
Duration: 4.0 hours

Description: The system was experiencing low Cathode inlet temperatures caused by a faulty Enthalpy wheel. The Enthalpy wheel was replaced.

System Number: SU01B000000176
Outage Date(s): 1/02/04
Duration: 56.7

Description: Through pro-active data reduction, noticed that power output was fluctuating. Found that a valve that provides water to the LTS Catalyst was leaking causing the temperature to drop. Replaced valve.

3.0 Unscheduled Outages

System Number: SU01B000000168
Outage Date(s):1/11/04
Duration: 86.7

Description: System shut down due to Humidifier water level low. The external DI water supply drain had frozen in the Mechanical room. The site Mechanical room was found to be malfunctioning. Once the heater was repaired the drain line was thawed and the system was restarted.

System Number: SU01B000000171
Outage Date(s):1/9/04
Duration: 258 hours

Description: The system shutdown due to a loss of Radiator fan. (Previously discussed in section 2.0) The system was thawed and restarted. This shut down occurred before root cause was found.

System Number: SU01B000000173
Outage Date(s):1/10/04
Duration: 59 hours

Description: The system shut down due to loss of Radiator fan. Thawed system and restarted.

System Number: SU01B000000173
Outage Date(s):1/15/04
Duration: 5.5 hours

Description: The system shut down due to low DI water level. The external DI water supply drain had frozen in the Mechanical room. The site Mechanical room heater was found to be malfunctioning. Once the heater was repaired the drain line was thawed and the system was restarted.

System Number: SU01B000000173
Outage Date(s):1/15/04
Duration: 120 hours

Description: The system shut down due to low ATO (Anode Tailgate Oxidizer) temperature. Found that system did not drain internal water upon shut down and froze internally. Frozen water was found to in the ATO/Humidifier assembly causing internal damage. The ATO/Humidifier assembly and two heat exchangers were replaced. System was restarted.

System Number: SU01B000000173
Outage Date(s):1/24/04

Duration: 96 hours

Description: System shut down for low ATO temperatures. This can be caused by the reformer producing poor quality gas. While system was down routine maintenance was performed. The natural gas desulphurization tank and system air meter was replaced. Upon restart the symptoms were still present. After taking reformer gas samples it was determined that the LTS (Low Temperature Catalyst) was spent. The Catalyst was replaced and the system was restarted.

System Number: SU01B000000174
Outage Date(s):1/09/04
Duration: 55.3 hours

Description: The system shut down due to loss of Radiator fan. The software was modified and the system was restarted.

System Number: SU01B000000175
Outage Date(s):1/09/04
Duration: 233.8 hours

Description: The system shut down due to loss of Radiator fan. Found ATO/Humidifier assembly had been damaged due to freezing. Replaced ATO/Humidifier assembly and restarted system.

System Number: SU01B000000176
Outage Date(s):1/09/04
Duration: 247.3 hours

Description: The system shut down due to loss of Radiator fan failure. The software was modified and the system was restarted.

4.0 Component Replacement

System Number: SU01B000000173
Replaced Component: HX1 (Glycol/DI water)
Date Replaced: 1/20/04
Total Component Run Hours: 6220

Description: Replaced Liquid to liquid heat exchanger

System Number: SU01B000000173
Replaced Component: HX3 (Glycol/Reformate)
Date Replaced: 1/20/04
Total Component Run Hours: 6220

Description: Replaced Glycol to reformate heat exchanger.

System Number: SU01B000000173
Replaced Component: ATO/Humidifier assembly
Date Replaced: 1/20/04
Total Component Run Hours: 6220

Description: Replaced due to damage to internal components caused by freezing.

System Number: SU01B000000173
Replaced Component: Air TSI meter
Date Replaced: 1/28/04
Total Component Run Hours: 6358

Description: Component reading incorrectly

System Number: SU01B000000173
Replaced Component: Desulphurization tank
Date Replaced: 1/29/04
Total Component Run Hours: 6372

Description: Reformate was showing signs of Sulphur breakthrough from tank.

System Number: SU01B000000173
Replaced Component: LTS Catalyst
Date Replaced: 1/29/04
Total Component Run Hours: 6372

Description: Reformer producing poor quality Reformate.

System Number: SU01B000000175
Replaced Component: Enthalpy Wheel
Date Replaced: 1/08/04
Total Component Run Hours: 6296

Description: The Enthalpy wheel was replaced due to the degradation of the core material.

System Number: SU01B000000175
Replaced Component: ATO/Humidifier assembly
Date Replaced: 1/20/04
Total Component Run Hours: 6350

Description: Replaced due to damage to internal components caused by freezing.

System Number: SU01B000000176
Replaced Component: LTS water Solenoid Valve
Date Replaced: 1/04/04
Total Component Run Hours: 6047

Description: Solenoid valve showed signs of mechanical failure. It was leaking internally.

5.0 Other Comments

The BTU meter measuring heat transfer for systems B168 and B169 failed and no thermal readings are available for the month. This same phenomenon has been experienced at the West Point fuel cell sites. The root cause is the aggressive nature of potable water and the constant introduction of deposit building material into the CHP loop. The result is heavy build-up on the flow meter moving parts. This eventually causes the meter to seize. A replacement meter has been installed and more frequent inspections of the loop will be made.

February, 2004 - Monthly Report

Pursuant to Contract # DACA42-03-C-0005

1.0 Summary/Milestones

February was a good month with an overall availability for the demonstration of 94.96%. All units ran at 2.5kW and the 10th month of operation was completed. In February there were several Humidifier water level sensors that failed. See section 5.0 for details.

2.0 Scheduled Outages

3.0 Unscheduled Outages

System Number: SU01B000000168
Outage Date(s):2/02/04
Duration: 4.6 hours

Description: The system shut down due to Humidifier high temperatures. The DI water RO filter ratio was recalibrated.

System Number: SU01B000000168
Outage Date(s):02/03/04
Duration: 10

Description: The system shut down due to Humidifier high temperatures. The Humidifier water level sensor was replaced and the system was restarted.

System Number: SU01B000000168
Outage Date(s):02/15/04
Duration: 19

Description: The system shut down due to Cathode Inlet Low temperature. The Enthalpy Wheel was replaced and the system was restarted.

System Number: SU01B000000169
Outage Date(s):02/16/04
Duration: 16.5 hours

Description: The system shut down due to Humidifier high temperatures. The Humidifier water level sensor was replaced and the system was restarted.

System Number: SU01B000000170
Outage Date(s):02/16/04
Duration: 7 hours

Description: The system shut down due to Humidifier high temperatures. The Humidifier water level sensor was replaced and the system was restarted.

System Number: SU01B000000174
Outage Date(s):02/13/04
Duration: 10 hours

Description: The system shut down due to Humidifier high Temperature. The Humidifier Level sensor was cleaned and reinstall. The system was restarted.

System Number: SU01B000000174
Outage Date(s):02/23/04
Duration: 35 hours

Description: The system shutdown due to low battery voltage. Found that the Enthalpy Wheel drain was plugged. The drain line was cleared and the system was restarted.

System Number: SU01B000000174
Outage Date(s):02/28/04
Duration: 25 hours

Description: The system shut down due to low battery voltage. Gas Samples were taken to insure the reformer was still producing quality Reformate. Samples were within specifications but slightly high. The Prox temperature was raised and the system was restarted.

System Number: SU01B000000175
Outage Date(s):02/16/04
Duration: 19 hours

Description: The system shut down due to loss of Radiator fan. Found that the Radiator fan was binding. The Fan Shroud was repositioned and the system was restarted.

System Number: SU01B000000175
Outage Date(s):02/18/04
Duration: 2.25 hours

Description: The system shut down due to Humidifier high temperature. The Humidifier water level sensor was cleaned and reinstalled. The external DI water panel filters were replaced and the system was restarted.

System Number: SU01B000000176
Outage Date(s):02/07/04
Duration: 52 hours

Description: The system shut down due to battery voltage low. Gas samples were taken and the results showed slightly high CO from the LTS Catalyst. The LTS temperature was raised to bring the Reformate back within specification.

System Number: SU01B000000176
Outage Date(s):02/10/04
Duration: 8 hours

Description: The system shut down due to Humidifier high temperature. The Humidifier water level sensor was cleaned and reinstalled. The external DI water panel filters were replaced and the system was restarted.

4.0 Component Replacement

System Number: SU01B000000168
Replaced Component: Humidifier water level sensor
Date Replaced:02/03/04
Total Component Run Hours: 6590

Description: Sensor fails to read accurately. The Sensor type has been changed in latest system design.

System Number: SU01B000000168
Replaced Component: Enthalpy Wheel
Date Replaced: 02/15/04
Total Component Run Hours: 6871

Description: The Enthalpy wheel was replaced due to the degradation of the core material.

System Number: SU01B000000169
Replaced Component: Humidifier water level sensor
Date Replaced: 02/16/04
Total Component Run Hours: 7607

Description: Sensor fails to read accurately. The Sensor type has been changed in latest system design.

System Number: SU01B000000170
Replaced Component: Humidifier water level sensor
Date Replaced: 02/16/04
Total Component Run Hours: 6200

Description: Sensor fails to read accurately. The Sensor type has been changed in latest system design.

System Number: SU01B000000174
Replaced Component: Humidifier water level sensor

Date Replaced: 02/13/04
Total Component Run Hours: 7923

Description: Sensor fails to read accurately. The Sensor type has been changed in latest system design.

System Number: SU01B000000175
Replaced Component: External DI water filters
Date Replaced: 02/18/04
Total Component Run Hours: 896

Description: The filters failed to supply enough DI water to the Fuel Cell. The filters were replaced

System Number: SU01B000000176
Replaced Component: External DI water filters
Date Replaced: 02/10/04
Total Component Run Hours: 7107

Description: The filters failed to supply enough DI water to the Fuel Cell. The filters were replaced

5.0 Other Comments

The BTU meter measuring heat transfer for systems B168 and B169 failed again. There are no Thermal readings are available for the month. This same phenomenon has been experienced at the West Point fuel cell sites. The root cause is the aggressive nature of potable water and the constant introduction of deposit building material into the CHP loop. The result is heavy build-up on the flow meter moving parts. This eventually causes the meter to seize.

March, 2004 - Monthly Report

Pursuant to Contract # DACA42-03-C-0005

1.0 Summary/Milestones

March was another good month with an overall availability for the demonstration of 94.9%. All units ran at 2.5kW and the 11th month of operation was completed. In February there were several Humidifier water level sensors that failed. See section 5.0 for details.

2.0 Scheduled Outages

System Number: SU01B000000170
Outage Date(s):3/09/04
Duration: 2.0 hours

Description: Through pro-active data reduction, lower than normal Prox temperatures were noticed. The system was voluntarily shut down to replace the Prox valve. The valve was replaced. The system was restarted. New SARC software was also installed.

3.0 Unscheduled Outages

System Number: SU01B000000168
Outage Date(s):3/07/04
Duration: 27 hours

Description: The system shut down due to the Inverter not exporting. The Inverter was powered down and then the system was restarted.

System Number: SU01B000000168
Outage Date(s):03/16/04
Duration: 30

Description: The system shut down due to Stack Cell trips. The Stack was replaced. The System was restarted.

System Number: SU01B000000168
Outage Date(s):03/29/04
Duration: 78.4

Description: The system shut down due to Stack Cell trips. It was found that the Reformer was making poor Quality Reformate, The Low Temperature Shift (LTS) catalyst and the Prox catalyst were replaced. The system was restarted.

System Number: SU01B000000169
Outage Date(s):03/1/04
Duration: 12.5 hours

Description: The system shut down due to Humidifier high temperatures. The DI water Transfer pump was replaced. The system was restarted.

System Number: SU01B000000169
Outage Date(s):03/25/04
Duration: 88.8 hours

Description: The system shut down due to Stack Cell trips. The Stack was replaced. The system was restarted.

System Number: SU01B000000171
Outage Date(s):03/12/04
Duration: 69.5 hours

Description: The system shut down due to a Methane sensor trip. It was found that the LTS pan had deteriorated. The LTS pan was replaced. The system was restarted.

System Number: SU01B000000173
Outage Date(s):03/29/04
Duration: 0 hours

Description: Noticed louder than normal noise coming from the system Radiator Fan. The Fan was replaced. No shut down required.

System Number: SU01B000000175
Outage Date(s):03/03/04
Duration: 22.5 hours

Description: The system shut down due to Humidifier high temperature. The external DI water Carbon filter was replaced. The system was restarted.

System Number: SU01B000000175
Outage Date(s):03/26/04
Duration: 4.5 hours

Description: The system shut down due to a Cathode low temperature. A poor wiring connection was found at the Power Distribution Board (PDB). The wire connection was repaired. The system was restarted.

System Number: SU01B000000176
Outage Date(s):03/24/04
Duration: 2.5 hours

Description: The system shut down due low battery voltage. It was found that the Reformer was making poor quality Reformate. The LTS temperature was raised. The system was restarted.

4.0 Component Replacement

System Number: SU01B000000168
Replaced Component: Fuel Cell Stack
Date Replaced:03/16/04
Total Component Run Hours: 7528

Description: The Fuel Cell Stack was replaced.

System Number: SU01B000000168
Replaced Component: LTS Catalyst
Date Replaced: 03/29/04
Total Component Run Hours: 7528

Description: The LTS was replaced due to it's inability to scrub CO from the Reformate.

System Number: SU01B000000168
Replaced Component: Prox Catalyst
Date Replaced: 03/29/04
Total Component Run Hours: 7528

Description: The Prox Catalyst was replaced due to it's inability to scrub CO from the Reformate.

System Number: SU01B000000169
Replaced Component: Di water Transfer Pump

Date Replaced: 03/01/04
Total Component Run Hours: 4451

Description: The DI water Transfer pump was replaced due to it's inability to pump water.

System Number: SU01B000000169
Replaced Component: Fuel Cell Stack
Date Replaced: 03/25/04
Total Component Run Hours: 7870

Description: The Fuel Cell Stack was replaced.

System Number: SU01B000000171
Replaced Component: LTS pan
Date Replaced: 03/12/04
Total Component Run Hours: 4128

Description: The LTS pan was replaced due to deterioration of the metal.

System Number: SU01B000000173
Replaced Component: Radiator Fan
Date Replaced: 03/29/04
Total Component Run Hours: 7835

Description: The Radiator Fan was replaced due to louder than normal noise emission.

System Number: SU01B000000175
Replaced Component: External DI water filter
Date Replaced: 03/29/04
Total Component Run Hours: 1263

Description: The External DI water filter was replaced.

5.0 Other Comments

The BTU meter turbine has been rebuilt and is once again operational as of 3/31/04. The plan is to monitor it weekly and attempt to obtain a complete month of thermal data to finish out the demonstration.

April, 2004 - Monthly Report

Pursuant to Contract # DACA42-03-C-0005

1.0 Summary/Milestones

April was another good month with an overall availability for the demonstration of 95.27%. All units ran at 2.5kW and the 12th and final month of operation was completed.

2.0 Scheduled Outages

System Number:
Outage Date(s):
Duration:

Description: There were no scheduled shutdowns in the month of April.

3.0 Unscheduled Outages

System Number: SU01B000000168
Outage Date(s):04/12/04
Duration: 7 hours

Description: The system shut down due to Humidifier high temperatures. The Humidifier water level sensor was replaced. The system was restarted.

System Number: SU01B000000174
Outage Date(s):04/04/04
Duration: 17 hours

Description: The system shut down due Humidifier Top high temperatures. There was a DI water leak at the LTS water solenoid. Replaced a Swagelock fitting and restarted the system.

System Number: SU01B000000175
Outage Date(s):04/05/04
Duration: 11 hours

Description: The system shutdown due to Cathode inlet low temperatures. It was found to be a poorly crimped wire connection at the Power Distribution Board (PDB). The connection was fixed and the unit restarted.

4.0 Component Replacement

System Number: SU01B000000174
Replaced Component: Swagelock fitting
Date Replaced: 04/04/04
Total Component Run Hours: 9093

Description: The fitting was replaced.

System Number: SU01B000000175
Replaced Component: Molex pin
Date Replaced: 04/05/04
Total Component Run Hours: 7014

Description: The Molex pin wire crimp was replaced.

5.0 Other Comments

The BTU meter turbine was rebuilt and reinstalled as of 3/31/04. The plan was to monitor to obtain a complete month of thermal data to finish out the demonstration. The Turbine failed again within two weeks. A complete discussion of the failed thermal monitoring equipment and lessons learned will be included within the final project report.